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Abstract

In this article, we expand on the relationship between the social processes of policymaking, management and research in the context of the Westerschelde estuary. This complex estuary system, located in Belgium and the Netherlands, has its own morphological and ecological characteristics and dynamics, and has three core functions: economically, it makes the port of Antwerp accessible; ecologically, it generates habitats for certain unique species; and in terms of safety, it prevents the hinterland from being flooded. We analyze how the social processes of policymaking, management and analysis have focused on these three aspects, and how they have affected the estuary.

We proceed to develop a framework for evaluating the social system of policymaking, management and research. This framework focuses on the social system's adaptive capabilities (how it evolved in a non-linear fashion), integrative capacity (how the system's interconnectivity was taken into account), and participative competencies (how the different interests and insights regarding the estuary were absorbed).

This framework was then applied to twenty years of policymaking about, management of, and research on the Westerschelde estuary. We conclude that, because of policy learning effects, policy/management and research take the estuary's self-organizing capacities into account much more than they did in the past. However, the self-referential behaviour of policymakers, managers and researchers makes it possible that an anthropocentric and technocratic approach towards managing the estuary, indicating a disconnection between the social and physical systems, could return.

1 Introduction

The Westerschelde estuary runs from the city of Antwerp in Flanders (Belgium) through the Dutch province of Zeeland and discharges in the North Sea. The estuary fulfils various functions for its societal environment. Firstly, it is the only maritime access from

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the sea to the port of Antwerp. Secondly, the estuary is an important subsystem within the ecological system. Thirdly, the estuary has a flood protection role. Contrary to other sea arms in the Dutch delta, which are closed by sluices and dams, the Westerschelde was never closed off.

These three (social) functions are as important as they are difficult to integrate. Good accessibility to the port requires deeper channels and frequent dredging of the ever-silting thresholds in these channels. However, these activities have two negative side-effects: the ecological value of the estuary is lowered, and the velocity of its currents and the volume of water increase, which is dangerous.

The tensions between these functions make the estuary a subject of fierce policy debates. The port authorities of Antwerp are constantly seeking to improve the access to the port. They need permission from Dutch authorities as most of the estuary's surface is located on Dutch territory. However, the Dutch authorities and stakeholders are more focused on the other functions.

Fulfilling these three demands largely depends on the systemic characteristics of the estuary. Knowledge about the estuary's development is essential for policy- making as well as for managing the morphology of the physical system. The physical system responds to social action and determines, to a large degree, the way in which policy makers can feasibly integrate the three objectives of accessibility, conservation and safety.

This article focuses on the interrelation between the social system and the physical system and its specific characteristics which forestall the full-fledged realization of these demands and pose specific demands on the way people deal with it. We are especially interested in the way the management, policy and research systems mediate between the social system and the physical system. We seek the following questions: Which demands for policymaking about, management of, and research on the Westerschelde estuary arise out of its social environment and which arise out of its physical characteristics and how did policymaking about, management of, and research on the estuary respond to these demands the last twenty years?

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The article proceeds in the following way. Firstly we identify the social system's demands on the management of and research on the estuary and the physical system's characteristics, with a view to understanding its demands on the management and research system.

We then focus on how these requirements are dealt with by the policy making, management and research systems and what the subsequent effects on the physical system are. Policy-making, management and research practises are analysed in three periods: from 1985 to 1997, from 1997 to 2001, and from 2001 to 2006. Each of these periods are characterised by unique social and physical dynamics and by visible differences in the way the policy, management and research systems operate. We show how their approach towards the Westerschelde estuary has evolved from an *anthropocentric* approach to a more *complex* and *ecocentric* approach, combining social and physical demands. While a more ecocentric approach could benefit the estuary (Corlay, 1993), we observe that a previously successful combination and integration of all three functions is no guarantee for continued success in the future.

Data was collected from multiple sources. We interviewed 30 participants, engaged in participative observation during meetings of officials, stakeholders, and experts over the last three years (2003–2006), and analysed policy documents and scientific research on the estuary, and particularly on its morphology.

2 Competing societal demands in the Westerschelde estuary

Human settlement on the borders of the Schelde placed growing demands on the estuary. There are three main conflicting societal demands that policy makers have to cope with: a need for safety, economic development and ecological sustainability.

These social demands are inherently in conflict. The most obvious conflict seems to be that between economic interests and ecological ambitions. For the several Schelde ports, quick, safe and regular access means a deep channel with as little as possible meandering and dampened tidal dynamics to guarantee efficient passage of ships

through the estuary. However, for the ecological-minded, such an approach would be destructive. Large canalization of the estuary would mean the end of its unique dynamics and of the inter-tidal areas with their valuable flora and fauna. Economic ambition also conflicts with the desire to guarantee safety from floods: increasing the accessibility of the estuary increases the amount of water within it, as well as the energy guided into the narrowly-embanked parts of the estuary. The inter-tidal areas and the many small trenches, on the other hand, help to dissipate most of the tidal energy and reduce the danger of flooding. Thus, ecological and safety interests are much more compatible, although classical approaches on safety were much less tolerant of ecological values.

These different societal demands have to be accommodated in policy-making on the Westerschelde. They are difficult to integrate because their effects on the constituting elements of the physical system are heavily interrelated. The morphological characteristics of the system include:

- The shape and depth of the different channels and bars within the channels, including the thresholds where channels cross one another- this is decisive for the accessibility of the ports;
- The amount of inter tidal areas and of low and high dynamic areas- this is important for the system's ecology;
- The fluctuations of tidal changes, the dissipation of tidal energy and the water storage capacity – this is important for the safety of the estuary and of the human activities around it.

Because the shape of the channel influences the amount, shape and robustness of the inter-tidal areas, it is difficult to balance economic and ecological demands. Since the shape of the solid barriers, such as dikes, influences the system's tidal dynamics, safety measurements aimed at strengthening these barriers affect the system's ecology. Finally, safety measures aimed at giving more room to the river enhance the

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possibilities for the natural system to improve but conflict with public opinion, which holds that setting dikes back diminishes the safety of the hinterland.

3 Complexity of physical characteristics of the Westerschelde estuary

An estuary can be understood as a complex adaptive system (Gerrits, 2008). Its elements are interconnected and it adjusts to changing circumstances (stemming from both human and natural causes). A complex system is complicated because its behaviour is erratic, non-deterministic, and therefore difficult to predict. This limits the ability of policymakers and managers to control the system and the ability of researchers to fully understand the system and its future state.

We distinguish between endogenous and exogenous complexity. Endogenous complexity refers to complexity generated by the estuarine components and their interconnectivity. An example is the dynamic mutual relationship between water and sediment. Deep channels with steep banks concentrate the energy of the water flowing in and out of the estuary, further deepening the channels. This improves accessibility, similar to that which occurred when the estuary and the river Schelde were connected, but can also lead to a loss of wetlands. In addition, deepening generates tidal effects that can easily lead to more intensive sedimentation, thereby creating new sand banks.

Exogenous complexity refers to complexity generated by incentives from outside the estuary, such as changes induced by humans to facilitate societal demands. An example is the construction of dykes. This influences the transport of sediment, and thus the overall morphology of the estuary. This sets off a chain of responses throughout the Westerschelde. The outcome is the same for dredging activities. Deepening is worth carrying out if it leads to faster movement of water outward. However, it can also lead to new tidal streams that will deliver much more sediment from the river or the sea. In this case, the physical system is responding or "fighting back". Thus, while dyke construction, dredging and aquatic disposal do impact the development of the estuary, it is very difficult to predict the causal relations that determine the course of events in

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the estuary (Peters et al., 2003).

Distinguishing between endogenous and exogenous complexity, and accepting that both exist and are interrelated, helps clarify the challenges policymakers face. To make sound decisions, they need to understand the outcomes of their actions; however, these outcomes are intertwined with the estuary's endogenous complexity.

This is a case of complex causation. Although all the elements are related to each other, the relationships cannot be fully understood, because they change, emerge or are discontinued over time. The Westerschelde is characterised by meandering channels that intersect, with shoals and sandbars in between. Its morphology is dynamic- channels and shoals migrate through the estuary due to sedimentation, sediment transport, accumulation and disposal. Sand is imported into the estuary from the North Sea and, in lesser amounts, from the Schelde River. The channels and bars continue to move throughout the estuary, degenerating and regenerating in an ongoing cycle (Koppel et al., 2005). Human-induced interventions (Peters et al., 2003; Gerrits and Marks, 2008), have an impact on this process, although the magnitude of these impacts is difficult to estimate. The morphological changes are thus influenced by endogenous as well as exogenous complex developments.

The main channels of the Westerschelde are used for navigation. As thresholds of sediments form wherever these channels intersect, maintenance dredging is required to keep these thresholds at the required depth as they obstruct navigation. The dredged material is usually stored in the estuary, either in the secondary channels or on the shoals located in between the channels. Both the shoals and the secondary channels are vital parts of the estuary's ecological state. Hence, any human activities, such as the disposal of dredged material, needs to take them into consideration.

The funnel shape of the estuary means that the energy of the water is concentrated towards the end of the funnel, i.e. at the port of Antwerp (Norga and Souwer, 2003). The presence of a diverse range of areas, such as shallow, deep and intertidal areas, helps dissipate the water's energy, and therefore increases the capacity of the estuary to absorb a sudden rise in the water level, which is an important feature in this flood-

prone region.

To sum up, there are three dimensions through which the estuary can be understood:

1. The estuary is dynamic with regards to the riverbed. Endogenous and exogenous variables change its state continuously, and also change the direction of change. This is the *non-linear* characteristic of a complex system. Social actors have to deal with the changes in the estuary's behaviour and with the possibilities of system leaps and system catastrophes.

2. The estuary consists of a variety of different (but interrelated) elements. These elements have different and changing attributes. For example, water can be fresh, brackish or salty, sediment consists of different grains, and the depth of the water changes constantly. While the estuary can be used for transport, it can also lead to flooding, help mitigate the impact of high tides, and can be seen as part of a larger feeding system for birds. The *diversity* of the estuary is apparent in how its many components possess a range of attributes, and is reflected in how various human interests are defended in the policy network around the estuary. All sorts of actors are involved in the policy process and attempt to generate support for their claims, related to some aspect of the estuary.

3. The Westerschelde estuary consists of various elements, which are all connected, i.e. developments in one element affect the other elements. Thus, the estuary is best understood as an interdependent system of physical elements. This *interdependence* is an important explanation for the trade-offs made among the different ambitions of the stakeholders who have a stake in the estuary. Improving the accessibility of the port of Antwerp has an impact on whether nature can flourish and could also necessitate additional investments to ensure safety. Thus, other stakeholders are unwilling to agree to channel-deepening investments because their interests could be harmed. These causal relationships between developments in the system are not linear. In other words, while deepening the estuary by one meter may not definitely cause inter tidal areas to be lost, the multiple channel

system can still be destroyed through a process of positive feedback, where a small change generates a chain of unforeseen effects.

If the overall goal is to manage such a complex system and craft adequate policies for it, thus implying that data has to be collected on which the policies can be based, the social systems involved in the estuary have to be able to deal with its complex characteristics (Hooke, 1999; Kay et al. 2003; Folke, 2006; Kotchen and Young, 2007).

The social organization of the estuary, in the form of its system of management, can be subdivided into two subsystems: a) policymaking and managing the estuary, and b) conducting research to obtain knowledge about the physical state of the system, its development and the expected impact of, for example, nature development projects, further deepening of the fairways, and investments in taller dikes. We consider the demands of the physical system on each of the subsystems in turn.

3.1 Demands of the estuary on the policy-making and management system

3.1.1 Non-linearity requires adaptive policies and management

In non-linear situations, management has to deal with unexpected events and developments, and has to be able to react quickly and flexibly to changes. Adaptive management (Walters, 1997; Rogers, 1998; Lee, 1999) fits these requirements. Adaptive management "formulates management policies as experiments that probe the responses of ecosystems as people's behaviour in them changes" (Lee, 1999(and needs "long-termism", adaptability, precaution and contingency (Stojanovic et al., 2004).

The responses of non-linear systems are unexpected and difficult to predict (Koppel et al., 2005). To be adaptive, a policy-making system has to invest in long-term strategies, respond to changes, and maintain flexibility in the means and ends it uses (Stojanovic et al., 2004). Also, management strategies need to be evaluated in a timely manner, so that operations can be adapted as soon as undesirable consequences appear.

Adaptive management looks beyond its own timeframe. Policies and strategies need to evolve when changing conditions require them to do so. In addition, non-linear systems, such as the Westerschelde, require a "trial-and-error" approach to ascertain what works and what does not. This is in contrast to a rigid implementation of a predefined vision with strictly defined policy goals over a long time span.

3.1.2 Diversity requires managing competing values

The estuary's diversity has both a social and a physical component. They are closely related as the estuary's properties affect the realization of specific interests or social demands. Specifically, the navigation channel accommodates the economic function, the inter tidal areas and the borders are ecologically valuable, and the dikes are necessary to safeguard the safety of the estuary. The water in general accommodates fisheries and recreation activities, and has to be of adequate quality to contribute to the general water quality in the delta.

These demands are in conflict, because the physical system's characteristics which enable them are interconnected so that one function can only be realized at the expense of another. These demands receive support from both within and outside the public domain. Therefore, in order to get support for policy measures, it is necessary that policy-making is consensus-oriented (Buanes et al., 2004) and that policies are comprehensive (Stojanovic et al. 2004; Foster and Haward, 2003).

In the case of the Westerschelde, the three social demands (accessibility, safety and nature quality) have their own protagonists and clearly compete against each other. Collaborative arrangements can help to reach solutions in which all relevant values are valued to some extent (Innes and Booher, 1999; Poitras et al. 2003).

3.1.3 Interdependence requires managing integrated subsystems

In a system in which all components are interconnected, management and policy-making that focuses on isolated components will fail. Fragmented approaches can

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have negative effects on an estuary where the fulfilment of its many functions depends on a sound balance between the system's different physical characteristics (Sadoff and Grey, 2002). The preparation and implementation of policy can only be successful once related components, such as dredging, restoring nature and navigation, are integrated, because of the negative effects that one-sided measures (favouring one particular goal) can have on the achievability of other goals in the estuary.

The interconnected character of the different elements of the estuary promotes the use of an integrated approach, and the literature on integrated coastal management (ICM) focuses on this. Integrated coastal management is a "multidisciplinary process that unites levels of government and the community, science and management, sectoral and public interests in preparing and implementing a program for the protection and the sustainable development of coastal resources and environments" (UNEP, 1999; Sorensen 1997).

3.2 Demands of the estuary on the research system

The physical characteristics of an estuary also set specific demands on the system of researchers and research institutes investigating the estuary. This system aims to understand the estuary as a functioning economic entity, as a protection system against flooding, as an ecological system, and also as an autonomous morphological system. This research system is important as a sense-maker for policymakers and managers.

3.2.1 Non-linearity requires longitudinal research

Firstly, it is important that the research system recognizes the non-linear character of the physical system. It has to take into account the characteristics of systems that are hard to predict. Therefore, research should be carried out over time, instead of focusing on a single point in time. Secondly, it should aim to articulate the range of uncertainties present and, if possible, should help actors become aware of the uncertainties surrounding non-linear systems. Learning by doing or trial-and-error approaches, are

the most promising strategies to obtain insights in complex systems (Walters, 1997; Meppem and Gill, 1998). Thus, to explore the main causal relations (if they exist), longitudinal monitoring and evaluation programs, covering extended time spans are necessary.

3.2.2 Diversity requires interactive research

The diversity of the physical system makes it necessary to organize broad, integral research programs. It also emphasizes the importance of interdisciplinary research and co-operation (Meppem and Gill, 1998). In addition, to take into account the different frames of reference of involved actors, pledges for joint fact-finding are often made (Ehrman and Stinson, 25). "Joint fact-finding is both a method for sound science-based decision making and a strategy for achieving stable agreements with widespread stakeholder support" (McCreary et al., 2001). The merits of "civic science" or collaborative analysis (cf. Korfmacher, 2002) have been spelt out in coastal management too. The implication is that research extends beyond scientific research and includes practical knowledge and even lay-knowledge, such as local experience.

3.2.3 Interdependency of the morphology's elements requires interdisciplinary research

The interdependency between the different elements of the physical system requires an interdisciplinary approach towards research and monitoring. Morphological, hydrological and ecological sciences should be developed in close interaction with each other to integrate knowledge about the relations between the different aspects of the system. In addition, a mixed scanning approach (Etzioni, 1967) can be useful: attempting to get a holistic insight into the whole system, while focusing on the relevant details when specific policy decisions have to be taken.

The effects of the estuary's physical and social characteristics on policy-making, management and research are summarized in Table 1.

To empirical analyse management and research practices, it is necessary to specify these requirements further. We do this by comparing options at both extremes for a) policy-making/management: non-adaptive management versus adaptive management, fragmented versus integrated management, unilateral and top-down versus consensual management, and b) research: design approach versus learning-by-doing, disciplinary versus interdisciplinary research, and expert rule (authoritative but mandated science) versus joint fact-finding. We include a number of operational characteristics in Table 2.

The anthropocentric style focuses on human interests and welfare that can be developed by using the estuary, without explicitly considering the needs of the physical system. The combined adaptive style takes into account the needs of the physical system without forgetting the human needs. This style can be contrasted with the so-called ecocentric (from ecology) approach in which the demands of the physical system are prioritised.

4 Case: developing the Westerschelde

The issue we are focused on is whether and how the afore-mentioned requirements are reflected empirically in the case study. The last two decades of policy-making and research on the Westerschelde have been marked by visible changes in the policy/management and research system, and the different phases of this change are analysed and compared. Finally, these differing management and research styles are related to the physical state of the estuary.

4.1 1985–1997: opposing neighbours and laborious negotiations

4.1.1 Policy-making and management

The management and policy-making of the Western Scheldt proved to be troublesome, especially with regards to discussions about deepening the main channel. The labo-

rious negotiations that led to the decision to deepen the channel took some 15 years (Meijerink, 1998). The Dutch government was not eager to deepen the channel as it could lead to a deterioration of the province of Zeeland's ecology, which would have to be compensated. Both countries viewed each other in a negative light, with the Dutch accusing the Belgians of gaining the profit from a deepening project and the Belgians accusing the Dutch of hindering their economic development in favour of Dutch ports. The final decision was taken in 1995, as part of a package deal between both countries.

As a result of the tensions in bilateral and intergovernmental relations, the estuary system was managed in a fragmented way, in terms of its functionality as well as scale. While research was strictly divided into Dutch and Flemish subsystems, co-operation between the Dutch and Flemish policymakers and managers was formal and bureaucratic. Specifically, the Flemish were responsible for the maintenance of the navigation channel, and the Dutch gave them the necessary permit for the dredging and disposal activities and monitored the effects.

The policy and management system was characterised by strongly divided approach: a few highly specialized agencies managed the estuary, in close interaction with public research institutes. There was thus much dissatisfaction among diverse interest groups. Many of them believed that, during this period, economic interests were given higher priority over ecological values. In addition, decentralized governments and interests groups on the Dutch side of the Westerschelde felt that they were neglected during the negotiations. Since the voices of the environmental interest groups were not heard, they fought out their conflicts with governmental agencies in judicial institutions (Meijerink, 1998), when a deal to deepen the channel was made.

The Technical Commission on the Schelde, responsible for the daily management of the Schelde, was a technocratic body and was positioned high in the hierarchy of the national civil service. Consequently, their attention to local and regional interests was low. The Westerschelde was much more of a negotiable asset for international diplomacy, than the joint responsibility of two countries. Thus, an anthropocentric management style dominated in this period.

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4.1.2 Research system

Similar to the management and policy-making system, the research system was subject to fragmentation and lack of co-operation. Expertise from both sides was not optimally used because of the strong institutional cleavages between both nations. The Dutch had built up a strong but hermetically closed research system. The standards of knowledge and technology were high, but appeared to be unresponsive to other opinions. Cooperation with Belgium was lacking due to the introversion of the Dutch research system, but also because of the lack of a suitable Belgian counterpart. Their research on morphology at that time lagged the Dutch, which hindered co-operation. An example of this is the research project East-West, which referred to the eastern part of the Western Scheldt were morphological stagnation had occurred. Although both countries possessed the solution for the problem, the project was a solely Dutch affair for a long time before the Belgians participated. Interaction with other stakeholders, namely environmental interest groups, was absent. Finally, experts were mobilized pragmatically: the ultimate decision to deepen the channel was taken without a fully completed environmental impact assessment (Meijerink, 1998).

4.1.3 Physical changes

This period was marked by a number of physical changes. The surface of the intertidal areas continued to decrease, a development that began some years earlier. The number of shallow water areas also decreased continuously. Another indicator for a change from a multi-channel estuary towards a single-channel water body is the erosion and ensuing transport of sediments, highlighting that the estuary imports sands from the North Sea during this period. The suspended material in the estuary fluctuated over time, increasing one year and diminishing the next. This was closely related to the sand mining operations. However, the suspended material was mainly found outside the navigation channel, a sign that the secondary channels were silting up. Finally, the tidal range continued to increase. This first period ended with the start of dredging

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operations for deepening the navigation channel.

4.2 1998–2001: cautiously together

4.2.1 Policy-making and management

The decision to deepen the Scheldt caused many legal and budgetary problems and many actors were dissatisfied with the situation. Before the deepening of 1997 was completed, the Port of Antwerp had already expressed a desire for further deepening of the navigation channel. In order to avoid the weaknesses of the previous policy process and outcome, the ministers of both governments decided in 1999 to develop a Long Term Vision on the Western Scheldt, marked by close co-operation between both governments and stakeholders. The stop-start policy strategy was abandoned. It was felt that any further deepening needed to fit into an integrated policy for the estuary. An extensive trajectory of research, deliberation and negotiation resulted in a broadly supported Long Term Vision in which five policy ambitions for the year 2030 were put down:

1. preserving the physical system characteristics of the estuary;
2. safeguarding the economic interests of the different ports;
3. prevention against floods;
4. improving the ecological situation of the estuary;
5. prolific and sustainable co-operation [30].

A concrete action program was formulated to realise this long-term vision. However, the process leading to the long-term vision was not without shortcomings. Firstly, the way in which the research process developed was troublesome. The morphological research for estimating the future development of the estuary and the possible effects

of a deepening on its morphology was set up and carried out exclusively by Dutch experts and research institutes. The Port of Antwerp responded by setting up a parallel research project. Both knowledge processes remained separated and no functional confrontation and joint analysis occurred.

Another important shortcoming was, again, the non-participation of regional governmental actors. The Long Term Vision was first and foremost the product of national governments and their specialised agencies. They learnt from the period prior to 1995 and involved interest groups in their deliberations to a certain extent, although decentralized governments were not invited.

Third, the process that led to the Long Term Vision was developed and managed by a small civil project team that stayed within existing organisations. That did not help arriving at an integrated management structure. Existing institutional routines and organisational interests were too dominant to make an effective collaborative process possible. The development of the Long Term Vision was also a very formal and political process in which there was little room for open, collaborative dialogue between the different governmental agencies and the stakeholders.

We see the management style as having developed somewhat. Although there are tendencies towards a more adaptive, integral, and consensual approach, they were a little half-hearted. Thus, the system was in a transition phase.

4.2.2 Research system

The way in which research was utilised for the Long Term Vision showed the same ambivalence. Experts saw it as their role to deliver the information officials need to make decisions. However, the research was not very detailed, and was more conceptual and approximate. In addition, external reviews of the different research projects were very critical of the lack of coordination and cooperation between the different disciplines. The lack of serious stakeholder involvement in the process meant that, in the near future, stakeholders were dissatisfied with the quality of the research results used to develop the Long Term Vision.

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4.2.3 Physical changes

The main physical change was the deepening that took place between 1997 and 1998. However, the results from this deepening, apart from the new depth, are not clearly reflected in the data, as morphological changes take considerable time to become visible. The total surface area of the intertidal areas continued to decrease, and at a faster pace than before the deepening. The decrease of shallow-water areas continued as well, but it was at a steadier pace than the decrease of the inter tidal areas. Sand import changed to sand export, i.e. more sand was transported to the North Sea or gained through sand mining than was imported from the sea. 1998 was the last year for which sand was imported; after that, it becomes an export product. This is the clearest change observed in this case (1985–2006). The volume of suspended material in the secondary channels continued to increase.

4.3 2001–2006: interactive and connected

4.3.1 Policy-making and management

The Long Term Vision was approved by the Flemish and Dutch governments. They agreed that, for the year 2010, a concrete Development Plan containing an integrated package of measures to realize a substantial part of the Long Term Vision had be delivered by a Dutch-Flemish project organization by the end of 2004.

A project organization called ProSes was established. This organization set up an intensive deliberation and negotiation process. The policy process was organized in collaboration with different interest groups, including the Port of Antwerp, environmental pressure groups, and governmental bodies.

The content of the Development Plan (issued at the end of 2004) reflected the high level of uncertainty about the possible effects of human intervention on the estuary. A special protocol was thus set up to deal with the hypothetical situation that the dredging activities led to the degeneration of the multi-channel system. Also, a long-term

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monitoring and research project was established to monitor the morphological developments within the estuary during and after the deepening.

The Development Plan also contained an experiment with an alternative dredging and disposal strategy, called 'morphological dredging'. This alternative took an offensive approach by focusing on nature restoration through dredging and both aquatic and inland disposal and careful monitoring. This trial-and-error approach was completely different from the existing policy in which dredged material could only be dumped within fixed locations, with negative consequences on the dynamics of the system (Peters et al., 2003).

Since the previous deepening, most parties involved seemed to have understood the weaknesses of that particular approach. The process discussed above showed considerable improvement over the previous approach. First of all, the degree of support for the proposal measures was considerably larger. The package deal (combining a deepening, developing nature, and investing in safety) was acceptable for most actors. Only the regional authorities of Zeeland disagreed with the Development Plan. However, in return for national funding for socio-economic investments, they agreed to refrain from (juridical) resistance against a further deepening of the Scheldt.

Second, there was no major debate over the main research findings regarding the estuary's morphology. This can be called a major result, given the high number of controversies that had risen in the past between different actors, even during the start of ProSes.

The most important problem regarding the Development Plan was the low attention given to agricultural interests, which now hindered the implementation of the nature development proposals: the creation of floodplains by dislocating dikes inland and thus reducing farmland. Because of the passive involvement of the agricultural interest group, no measures had been developed that integrated agriculture with nature conservation.

The Development Plan reflects some key characteristics of *adaptive management*. The actors agree that, once undesirable effects of the deepening appear, the intended

operations should be altered or abandoned. Also, attention was paid to the potential of using a trail and error approach, especially with regard to the dredging and disposal strategy.

The project organisation as a working form proved to function well for an *integrated approach*, as it incorporated the interdependencies of the different aspects of the estuary. Because of the involvement of almost all relevant actors, the policy proposals reflected the most important aspects of the estuary. However, the limited involvement of agricultural interests and the organizations in charge of water management (the Water Boards) remains a weakness of the ProSes approach, especially with regard to the nature conservation proposals. Nature conservation requires the transformation of farmland and changes to the water system, which is the responsibility of the Water Boards. After a while, their resistance to the proposals was supported by the Dutch Parliament, which delayed approval of the Development Plan before the nature projects were amended in favour of agricultural interests.

4.3.2 Research system

The research was organized in close interaction with stakeholders. For example, the Port of Antwerp's research team participated in Working Groups and expert panels. Their ideas for a more empirical and experimental approach toward the estuary were integrated in the final Development Plan. PAET proposed a large-scale experiment to find out the actual reaction of the system on human intervention. This research project was intertwined with the formal strategic environmental impact assessment. The decision to deepen the navigation channel was accompanied by a decision to set up a long-term monitoring program to keep an eye on the system and its behaviour after this intervention. It was agreed that, if negative developments occurred, the deepening would be cancelled.

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4.3.3 Physical changes

It is difficult to obtain meaningful analysis of the physical changes during this period as the data has not been processed yet. Sand exports appear to have continued. The question of whether more sand will be imported or exported in the near future is still unanswered. There also seems to a trend towards more flood dominance, although more data is needed to confirm this observation. A direct operation is an empirical test at the Walsoorden location, during which dredged material is applied to the tip ends of the shoal to regenerate its capacity to maintain itself. The test has been deemed to be successful, which in turn opens up the possibility of extending this strategy elsewhere in the estuary during the future broadening.

5 Congruence between the physical and social system?

Throughout the years, the actors involved in managing the Scheldt estuary gradually replaced the anthropocentric approach with a more ecocentric-oriented approach. More attention has been paid in the last decades to combining the necessary components in the different approaches. For example, social actors have developed a more cooperative strategy to combine their own goals with the physical development of the estuary in a sustainable way. Also, researchers and policy makers recognise that joint fact-finding and integrated, ongoing research is necessary to deliver adequate knowledge that is practically applicable.

Recently, the management of the Westerschelde has adjusted its proposals and strategies to match the requirements of the physical system. This was possible because the main physical changes are better understood than in the past and are better communicated with the policy and management system. This approach, which accepts increased complexity of the estuary, is applied to prevent unforeseen and unfavourable effects of social intervention and to safeguard the physical health of the system. It has become the main starting point for policy and management.

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When the demands placed on the social system by the physical system of the estuary are compared over the past two decades of policy, management and research on the Westerschelde, a learning effect can be observed. This first became visible when the Long Term Vision was prepared, and has, even though some weaknesses remain, become clearer during the last few years when the ProSes organisation was operating.

We can witness a couple of signs that illustrate a growing congruence between management and research and the physical characteristics of the estuary. These observations underline our argument that policy-making and research approaches that are more congruent are better able to safeguard the estuary's dynamics and health.

- The anthropocentric dredging and disposal strategy of the 1990s has been abandoned because of its negative effects. It led, among others, to the immobilisation of sediments and strains on the multi-channel character of the estuary. A more adaptive morphological management strategy has developed. The experimental testing of disposal strategies is a new adaptive strategy in the estuary that seems to work better than the former (rigid and fixed) dumping strategy that resulted in a stiffening of the eastern part of the estuary;

- The combined style based on the idea that ecological development and accessibility are not a priori adversaries, but can benefit from each other, was operationalised in the so-called "morphological dredging" technique. This method could be developed because of the more adaptive and integrated behaviour of the policy, management and research social subsystems.

- Contact between ecological and morphological experts from different disciplines generated a more rounded view of the ecological value of different dimensions of the estuary. Dutch morphological research traditionally focuses on macrodynamic processes within the riverbed, while ecologists are interested in microdynamic processes in specific ecologically-valuable areas. This detailed focus had added value for the complex estuary system, as it helps to find and allocate promising locations for nature development;

– The joint fact-finding process of ProSes forces long-term modelling researchers to adopt a more empirical approach, instead of a formal mathematical approach. That made a more refined intervention approach possible, in which fine-tuned human interventions steered the estuary's physical processes;

– The current social system that interacts with the Westerschelde understands that each function of the physical system has to be developed in relation to other functions. This view is held among both governments and stakeholders. Consequently, these functions are included in package deals. Anthropocentric decisions to deepen the navigation channel without looking at the negative effects are not longer feasible;

– The negotiations over the current proposals include investments in research and monitoring, nature development and safety measures. There is also more attention to the uncertainties and risks of deepening. The interdisciplinary and bilateral monitoring program will be better able to detect negative developments within the estuary at an early stage.

6 Reflection

Central to this article is the mutual interaction between social and physical systems and the way the variety of demands that stem from both systems can be accommodated by policymakers, managers and researchers. In the case of the Westerschelde, we observe a tendency towards combined styles of policy-making, management and research. By doing so, actors learned to cope with the dynamics of the estuary more consciously. Actors developed new ways of operating, new frames of mind and more realistic interpretations of each other and of the behaviour of the estuary. This increasingly adaptive approach is valuable as it helps deal with the multiple assumed conflicts.

However, fallback will occur as soon as new (political) parties entering the social systems view the estuary as a bargaining asset, and policy agencies and research

institutes regard the physical system solely as their engineering challenge. The first signs of this are already visible at the time of writing. Due to the societal resistance against land reclamation, the proposed nature development runs the risk of being delayed or marginalized. If that happens and the deepening is pushed through, nature restoration will not take place and the physical characteristics of the estuary may be threatened. The measures being proposed now are already less far-reaching then originally intended in the Developmental Outline.

In addition, the necessary change in orientation among the many actors involved has to be accompanied by major revisions in the institutional structures of policy-making, management and research. This will help to make adaptive, integral and fine-tuned management interventions possible and endure longer. The routines being developed now are loosely coupled to the existing bureaucracies and were developed in temporal arrangements and forums. However, they have to become embedded in the existing organizations to reduce the risk that actors forget them or choose strategically traditional egocentric instead of ecocentric approaches.

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Table 1. Demands on the policy/management and research system.

	Non-linearity	Diversity	Interdependence
Demands on policyand management system	Adaptive management: mutual adjustment, trial and error, flexible and non-blue-print	Consensual management: trying to find solutions that serve the interests of as many as possible aspects	Integrated management: trying to surpass territorial and functional cleavages, cooperation, coordination
Demands on research system	Learning by doing Long-term monitoring Uncertainty management	Joint fact-finding, interactive science.	Interdisciplinary and collaborative research

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Table 2. Contrasting management styles to deal with physical systems.

Anthropocentric policy and management style	Combined adaptive policy and management style
Non-adaptive management: management based on political or technical ambitions. Policy ambitions are based on political or other ideals and are rigorously implemented	Adaptive management: management tries to respond to and anticipate the behaviour of the physical system Central question is: how can political ambitions be combined with the characteristics of the physical system, and carried out with respect to these characteristics?
Fragmented management: organisations involved execute their own job, without paying attention to the tasks and priorities of other organisations Few, if any, contacts between organizations and few if any interaction arrangements	Integral management: organizations involved try to coordinate their actions in order to realise collective ambitions Decisions are made by consulting and activating the different organisations involved in the policy and implementation network
Unilateral management: central (principal) organisation makes crucial decisions unilaterally Decisions are made by political central bodies (parliament, ministers). Regional governments and stakeholders are marginally involved or not at all.	Consensual management: stakeholders and officials try to reach broadly-supported decisions Collaboration between governments and stakeholders Actors try to reach shared ambitions and/or package deals

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Table 3. Contrasting research styles to deal with physical systems.

Anthropocentric research style	Combined research style
Design approach: research develops tools that make the realization of political or technical ambitions possible, without serious attention to the physical behaviour of the system; researchers investigate the optimal use of the estuary for humans	The physical system is perceived as a living system with its own needs and behaviour. The vitality of the morphological system is investigated, along with human needs.
Research questions are deduced from policy ambitions and meant to answer to the question: how can we implement this solution? Research output is handed over from the research to the policy/management system	Research is based on the complex and dynamic interrelation between elements and subsystems. Research is integrated in the policy process and, during the interaction, policy ambitions and methods are developed. Practice leads.
Disciplinary research: focusing on the reality of a single organization that is doing its own job.	Interdisciplinary research focusing on the multiple realities of several involved organizations and combining the variety of insights and knowledge into a joint understanding of collective needs and actions.
Focus on disciplinary research within own institute, within one framework of assumptions, models and practices. Little interaction between research institutes and between disciplines (normal science)	Research is set up around integral research questions and in an interdisciplinary, or at least multidisciplinary, research program. Collaboration between different (competing) research institutes (mode two science)
Expert rule: dealing with the needs of the principal as distinctively as possible.	Joint fact-finding: the research process is set up in close interaction with stakeholders and officials
Political or societal interference in the research process is rejected. No negotiations about and adjustments of research results possible.	Stakeholders involved in the research process: formulation of research questions, selection of data, models and interpretation methods, formulation of conclusions
Experts protect their expertise and conclusions from the opinions of stakeholders.	

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Table 4. Management style 1985–1997.

Anthropocentric management style	
Non-adaptive management:	Political negotiated ambitions prevail in management. Physical developments in the estuary are little-known and not taken into account in policy development and management. Political deals are marginally evaluated for their impact on the physical system.
Fragmented management:	Little interaction between Flemish and Dutch governmental bodies. Both governments defend their own interests. No integration between regional, national and aspect-specific ambitions: functional and territorial fragmentation. Ambitions of stakeholders remain opposite.
Unilateral management:	Led by the managerial decisions of the TCS and the political decisions of ministers. No serious involvement of other actors.

Table 5. Research style 1985–1997.

Anthropocentric research style	
Design approach	Political decisions lead, as science is used to guide the implementation trajectory.
Fragmented research	Interdisciplinary insight in complex interactions in physical system is not developed. There is no interaction between institutes of different countries: they use their own methods, data et cetera.
Expert rule	No discussion about scientific procedures. Knowledge of own institutes is not confronted with counter knowledge. No interaction with other actors.

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Table 6. Management style 1998–2001.

	Mixed management style
Semi-adaptive management	More adaptive: physical system characteristics are points of departure for formulating policy ambitions (ambition 1 of LTV)
Semi-integral management	Cautious start of more integrated management through the start of a project team. But little interaction with regional governments.
Semi-consensual management	Stakeholders involved, but decision-making highly focused on ministers and TCS.

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Table 7. Research style 1998–2001.

Technocratic research style	
Design approach	Design approach: how to combine the different policy ambitions? No attention to alternative options
Fragmented research	Fragmented research: no interdisciplinary research. No coordination between national institutes
Self-referential science	No serious stakeholder involvement in research process.

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Table 8. Management style 2001–now.

	Combined adaptive management style
Reflexive management	More adaptive: physical system characteristics are points of departure for formulating policy ambitions. Flexible dumping strategy is part of policy. Also, more trial-and-error because of the proven weaknesses of the current rigid approach
Integral management	More integral management through semi-permanent project structure. Enduring collaboration of different governmental authorities and stakeholders.
Management of competing values	Stakeholders have an official position in policy process and subsequent management trajectory. To some extent, Development Plan contains attractive elements for all parties.

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Table 9. Research style 2001–2006.

Mixed research style	
Learning by doing?	Design approach but also trial-and-error: official institutes focus on answering research questions derived from policy ambitions. Alternative research focuses on experiments.
Interdisciplinary research	First attempts at interdisciplinary and bilateral research. Establishment of an extensive interdisciplinary research project
Joint fact-finding	Stakeholders advise the experts. Parallel research is intertwined with the official research,

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